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# 10 Ski-piste revegetation promotes partial bird community recovery in the

## 11 European Alps

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## 30 Abstract

31	Capsule Restoration of grasslands on ski-pistes caused a recovery in the bird community, but not to
32	the extent that it was equivalent to a natural Alpine grassland community.
33	Aim To test whether revegetation of ski-pistes in open habitat areas results in bird community
34	recovery.
35	Methods The bird communities in two ski resorts in the Italian Maritime Alps were surveyed using
36	a standardized area count method in three different plot types: non-restored ski-pistes (newly
37	constructed), restored ski-pistes and control plots in grassland far from ski-pistes.
38	Results In 49 independent plots, 32 species were recorded. Species richness and abundance of birds
39	were significantly higher on restored than on non-restored ski-pistes, independently of the species
40	group considered and the analyses carried out. Bird community parameters of restored ski-pistes
41	were still lower than those of natural grassland, as shown by results of typical grassland species.
42	Conclusion Our results suggest that an apparently successful restoration of ski-pistes may be not
43	enough to promote a complete recovery of bird communities. The complete recovery of local bird
44	communities may be promoted only if an integral recovery of the original vegetal communities is
45	achieved. We suggest the best conservation option is to adopt techniques to maintain as far as
46	possible original grassland if construction of new ski-pistes is unavoidable.
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55 Introduction

56 Over the last century, the European Alps have been subject to an increasing anthropogenic impact 57 due to the building of ski-pistes and the development of winter tourism facilities (Simons 1988; Mackenzie 1989, Pechlaner & Tschurtschenthaler 2003). The skiing industry is of major economic 58 59 importance in the alpine region, and it has recently experienced a period of great expansion (Koenig 60 & Abegg et al. 1997; Elsasser and Messerli 2001; Wipf et al. 2005). Several thousands of kilometers of ski-pistes are used for downhill skiing (Rolando et al. 2007), and in the Swiss Alps 61 alone about 220 km<sup>2</sup> are directly affected by ski-pistes (Amacher-Hoppler and Schoch 2008). 62 The main impact of ski-pistes is on vegetation and soils, since the natural vegetation and most of the 63 64 upper soil horizons are removed during the construction process (machine grading, used to smooth 65 out underlying rock and soil), to provide suitable slopes for skiers and to enhance the use of artificial snow (Mosimann 1985; Wipf et al. 2005; Isselin-Nondedeu & Bédécarrats 2007; Delarze 66 67 and Gonseth 2008). Moreover, the use of snow-grooming vehicles in the preparation of pistes 68 causes changes in the underlying soil structure and vegetation (Cernusca et al. 1990; Rixen et al. 69 2004). Finally, summer management at regular intervals, involving cutting of shrubs and machinegrading, produces further damage to vegetation (Bayfield 1996; Titus & Tsuyuzaki 1999). The 70 recovery of vegetation may be successful below the treeline, whereas it is extremely difficult above 71 72 the treeline, because of the scarcity of soil and the peculiar traits of high altitude plant species (very 73 low growth rates, low seed production and the insufficient agents of seed dispersal; Urbanska and 74 Fattorini 2000). 75 In addition to the apparent negative effects on soils and vegetation, the impacts of winter recreation 76 are most often negative for fauna. Results from meta-analyses have shown that richness, abundance

- and diversity of fauna were lower in areas affected by winter recreation when compared to
- vundisturbed areas (Sato et al. 2013). Several studies have shown negative effects of ski-pistes on

79 animals, i.e. birds (Laiolo & Rolando 2005; Rolando et al. 2007, Patthey et al. 2008, Caprio et al 2011), small mammals (Hadley & Wilson 2004; Sanecki et al 2006; Negro et al. 2009, Rolando et 80 81 al. 2013), reptiles (Sato et al. 2014a,b) and invertebrates (Negro et al. 2009, 2010, and 2013, Rolando et al. 2013, Kessler et al. 2012, Kašák et al. 2013). 82 Below the treeline, ski-pistes through forest may induce habitat fragmentation that limits small 83 84 mammal movements (Negro et al. 2012), whereas above the treeline they likely do not significantly 85 cause habitat fragmentation, but landscape changes may nevertheless affect bird species richness and distribution (Caprio et al. 2011). The area above the treeline is of particular concern, because 86 87 climate changes will probably induce operators and stakeholders to shift skiing activities and ski-88 pistes to higher altitudes (Elsasser and Messerli 2001; Fukushima et al. 2002; Bicknell and 89 McManus 2006; Scott et al. 2008) where ecosystems are particularly sensitive (Körner 2003). The scarcity of vegetation on ski-pistes of high altitude grasslands is likely the most relevant 90 91 determinant of bird diversity. Sparsely grass-covered ski-pistes are landscape features which lower 92 grassland species richness and probability of occurrence of certain passerine species (Caprio et al. 93 2011). Moreover, the amount of grass vegetation controls abundance and diversity of ground dwelling arthropods (Negro et al. 2010) that, in turn, may directly affect birds feeding on 94 95 invertebrates (Rolando et al. 2007). In general, a further problem regards detecting habitat effects at community levels. A completely holistic approach may be unsatisfactory because different species 96 97 often react differently to the same environmental factors, therefore communities are often split into guilds, which group animals according to their eco-ethological characteristics (Verner, 1984). The 98 99 response of specialist species (i.e. grassland species) may be therefore different to those species that 100 are more associated with shrubs and forests (Laiolo et al. 2005, Rolando et al. 2007). 101 In this paper, we tested the hypothesis that revegetation of grassland ski-pistes promotes bird 102 community recovery. We considered ski-pistes located in pastures ranging from about 1500 to 2200 103 m a.s.l. at two ski resorts in the Maritime Alps (the southernmost part of the Alps). Here, due to the low altitude of several ski-pistes and the influence of the maritime climate, old ski-pistes have been 104

105 recolonized by vegetation and are nowadays grass-covered. Other, more recent, ski-pistes have not 106 recovered and appear as strips of bare ground with scarce vegetation. We therefore compared whole 107 bird community and guild diversity in plots located in i) ski-pistes of recent construction with 108 depleted or no vegetation (hereafter non-restored ski-pistes), ii) old ski-pistes that were entirely grass-covered, showing a rather natural appearance (hereafter *restored ski-pistes*), and iii) natural 109 110 grasslands. We also investigated bird-habitat relationships, to identify structural components of the 111 habitat (e.g. grass cover, shrub cover, height of vegetation etc.) that control composition and 112 abundance of grassland bird communities.

113

#### 114 Materials and methods

#### 115 Study Area

116 The study was carried out within the Limone and Limonetto skiing districts in the Vermenagna 117 Valley (south western Italian Alps) (44° 11'N 7° 33'E), partly encompassed within a protected area 118 (Site of Community Interest IT1160056 "Alpi Marittime"). Beech Fagus selvatica forests extend all 119 over the area, but large pastures also occur at the same altitude as forests from 1500 m a.s.l. 120 upwards. Pastures are characterized by *Nardus stricta* prairies interspersed with shrub patches 121 represented by juniper Juniperus communis, alpen rose Rhododendron ferrugineum and, to a lesser 122 extent, bilberry Vaccinium myrtyllus. They are the outcome of intensive historical pastoral activities 123 that at first removed beech forests and then maintained open habitats. Cattle and sheep, even though 124 pastoralism is declining, are still present in the area.

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126 We considered all the ski-pistes of the study area (a total of 53 kilometers), but sampling was

127 carried out in open habitat only, i.e. where tracks cross open pastures, from about 1500 to 2200 m

- 128 a.s.l. Restored ski-pistes are 3-10 years old and are still in use but show in most cases a natural
- appearance, with a rather high grass cover. This depends on land use and climatic peculiarities of

130 the study area. Because of the long history of pastoralism, open habitats also occur below the tree 131 line that, due to the influence of the sea (the distance between Limone Piemonte and the Ligurian 132 sea is less than 50 kilometers), is set at a rather high altitude (about 1800 m for the beech and 2500 133 m for the larch Larix decidua). Most of the open habitat ski-pistes are therefore below the natural tree line and because of this, their restoration (partly due to natural dynamics and partly due to 134 135 artificial seeding) is quicker and more successful than that of other alpine localities where open 136 habitat ski-pistes are located above the tree line. Moreover, during construction, original grass and 137 topsoil were not removed everywhere; smooth pastures, in particular, were left untouched. Restored ski-pistes were not machine-graded during summer. Conversely, non-restored ski-pistes are of 138 139 recent construction (1-2 years) or have experienced recent summer machine grading and appear as 140 strips with bare ground either without grass, or with a very few dispersed grass tufts. In most of the ski-pistes, snowmaking is used to supplement natural snow during the winter season. 141

142

#### 143 Bird and habitat surveys

144 Field work was carried out in the morning, during the first 4 h after sunrise, in June and July 2011 145 by EC, who sampled birds using a standardized area count method, surveying birds in circular plots 146 of 50 m radius. Counts lasted 15 min, during the first 10 minutes of which the observer stood still 147 and quiet at the centre of the plot, as in standard point counts. In the last 5 minutes of the count, the 148 observer moved around, to flush secretive and non-singing individuals, and stopped at suitable vantage points to look and listen, recording all birds seen or heard within the plot (Laiolo et al. 149 150 2004, Rolando et al. 2007). Each census plot was visited twice (in June and July); the total number 151 of species from the two censuses was used as a measure of species richness, and the higher number 152 of individuals over the two visits was used as a measure of bird species abundance per plot. Three types of plots were defined: plots centered on non-restored ski-pistes (n = 14), on restored ski-pistes 153 154 (n = 17) and in natural grassland habitats (n = 18). Points were selected on the basis of accessibility, also avoiding sources of possible disturbance (i.e. close to roads or livestock), or locations where
detectability may have been reduced. At the same time, we kept other landscape features as constant
as possible (i.e. distance to forest, slope, exposition and altitude).

158 When possible, sampling was organized in sets of three, the plots of the three types being located in

the same skiing district with the same landscape and topography (see above). Ski-piste strips were

160 65-185 m wide (mean  $114.2 \pm 38.5$  SD); when the strip was narrower than 100 m (restored ski-

161 pistes n = 2, non-restored ski-pistes n = 3), a variable portion of open habitat at the side of the ski-

162 piste was included in the plot. Plots were set at a minimum distance of 300 m. Avian communities

163 were described in terms of two diversity parameters, species richness (S) and total abundance.

164 Following Laiolo et al. (2005), species were classified as ecotone/grassland or shrub/woodland

according to their ecological preferences.

Altitude and seven habitat cover and structure variables were collected for each plot: percentage of shrub, stone-rock, soil-rubble (i.e. open-ground) and grass (all coverage estimated by eye), Shannon diversity of the vegetation (Shannon Index,  $H' = -\sum p_i * \log(p_i)$ ), where  $p_i$  is the relative frequency of species i calculated according the relative frequency of vegetation types (area of grass, juniper, alpen rose and other bushes estimated by eye), mean height of the vertical component of the habitat (mean of 20 measurements of shrub, stone-rock, soil-rubble and grass per plot, shared according to the relative cover percentages and recorded with a wooden dowel subdivided into 1-cm units) and

heterogeneity of the vertical component ( $CV = SD/mean \times 100$ ).

- 174 percentage of shrub, stone-rock, soil-rubble
- **175 Data Analysis**
- 176 Differences between plot types
- 177 *a)* Habitat

178 Differences in habitat cover (i.e. shrub, stone-rock, soil-rubble and grass cover) and habitat

179 structure (i.e. H' of vegetation cover, mean height and CV of vertical structure and heterogeneity)

180	between the three plot types (i.e. non-restored ski-pistes, restored ski-pistes and natural grasslands)
181	were tested by means of one-way analysis of variance ANOVA. To attain the normal distribution,
182	the values of Shannon index were log transformed [y=log(x+1)]. Factor analysis (FA; Gaunch
183	1984) was chosen to reveal patterns in the data for habitat cover and structure (i.e. the seven
184	variables listed above).
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#### 186 *b)* Bird communities

187 Differences in mean bird species richness and total abundance were tested by means of one-way 188 ANOVA. To attain the normal distribution, the values of species richness and total abundance were 189 transformed to square roots  $[y=\sqrt{(x+0.5)}]$ .

190

### 191 *Relationships between bird community and habitat*

192 We tested for the effects of habitat cover (percentage of shrub, stone-rock, soil-rubble and grass 193 cover), habitat structure (H' of vegetation cover, mean height and CV of the vertical component of 194 the habitat), plot type (categorical variable defining plots in natural grasslands, in non-restored and 195 restored ski-pistes) and altitude on bird species richness and abundance of individuals using 196 Generalized Linear Models (GLM). To reduce correlation among variables, we first examined all 197 pair-wise correlations to identify strongly correlated pairs (r > |0.7|). The result of this preliminary 198 analysis showed that none of the above habitat cover and structure variables were highly collinear. To model the distribution of species richness and abundance of individuals, count (i.e. number of 199 species or individuals) was modeled specifying a Poisson error distribution and a log link function. 200 201 Full models were subject to a model reduction procedure whereby non-significant terms were 202 sequentially dropped from a model until only significant terms remained. Since initial models of abundance of individuals showed over-dispersion, we used a quasi-Poisson error distribution model. 203

204	In addition to the full model which tested habitat cover, habitat structure and plot type as covariates
205	we ran separate models with only habitat cover and structure variables (i.e. percentage of shrub,
206	stone-rock, soil-rubble and grass cover, H' of vegetation cover, mean height and CV of the vertical
207	component of the habitat and relative heterogeneity) or only plot type (i.e. natural grassland, non-
208	restored and restored ski-pistes),

to verify through AIC which set of variables carried more information. Generalized linear models
were calculated with R 15.0.1 (R Core Team 2014).

### 211 **Results**

We conducted surveys at 49 independent plots ranging in altitude from 1478 m to 2250 m (mean: 1812±161.5m). 32 species were detected, of which 24 were grassland or ecotone species and eight were shrub or woodland species (see Appendix I). Whinchat *Saxicola rubetra*, water pipit *Anthus spinoletta*, black redstart *Phoenicurus ochruros* and linnet *Linaria cannabina* were the most common species, with frequencies of occurrence (the number of times species were observed within 98 samples) higher than 10%.

218

### 219 Differences between plot types

220 *a)* Habitat

221 Non-restored ski-pistes showed a significantly lower percentage of grass cover and average vertical

structure and a higher soil rubble cover than natural grassland and restored ski-pistes. No significant

- habitat difference between restored ski-pistes and natural grassland was found (Table 1). Shrubs
- (especially rhododendron) were found in natural grasslands only (an average cover of  $4.58 \pm$

13.67%), because they were removed from ski-pistes during construction.

Factor analysis showed that the first two principal components (PC1, PC2) accounted for 70.06% of

the total variation in the habitat structure matrix, with eigenvalues > 1. The percentage of soil-

228 rubble and the heterogeneity of the vertical component had a negative contribution on PC1 229 (suggesting a gradient of grass cover from bare ground to pastures) and the percentage of rocks and Shannon index of vegetation cover provided the major positive loading on PC2 (suggesting a 230 231 gradient from grassland-dominated plots to more diversified plots with shrubs and rocks). The 232 relative position of centroids (i.e. the average location of survey plots in ordination space) in the 233 biplot determined by the first two principal components showed that natural grassland and restored 234 ski-pistes were structurally quite similar, and very different from the non-restored ski-piste 235 category, which was identified mainly with soil-rubble cover (Fig. 1).

236

#### 237 *b)* Bird communities

238 Non-restored ski-pistes, restored ski-pistes and natural grassland plots showed significant 239 differences in terms of species richness and abundance of individuals (Table 1). Plots located in 240 natural grasslands supported the highest bird species richness and abundance, whereas those set in 241 non-restored ski-pistes had the lowest values. However, differences between restored ski-pistes and 242 natural grasslands depended on whether all species or only grassland species were taken into 243 account. When all species were considered, post-hoc tests showed that species richness was not 244 significantly different between plots in natural grasslands and those in restored ski-pistes (even 245 though values were lower in the latter), whilst the abundance of individuals was significantly 246 greater in natural grassland. When only grassland species were considered, pairwise post-hoc tests 247 showed that both ecological parameters (species richness and abundance) were significantly lower 248 on restored ski-pistes than in natural grassland (Table 1, Fig. 2 and Fig. 3).

### 249 Relationships between bird community and habitat

Generalized linear models showed that bird community parameters (species richness and abundance) of both non-restored and restored ski-pistes were significantly lower than those of natural grassland (reference category) independently of the community composition (Table 2). Notably, differences in the abundance of individuals of grassland species of restored ski-pistes and of natural grasslands were highly significantly different (P < 0.001), whereas the differences regarding the overall community were less striking (P < 0.05).

256 Bird communities were also influenced by two habitat structure variables, shrub cover and 257 vegetation diversity; grassland species were also positively influenced by altitude. As a rule, 258 community parameters increased with vegetation diversity (3 instances out of 3) and decreased with 259 shrub cover (3 out of 4). In general, separate models with only plot type carried more information 260 than those with only habitat cover and structure variables (Total species richness: plot type only model AIC 233.64, vegetation only model AIC 254.54; Grassland species richness: plot type only 261 model AIC 223.91, vegetation only model AIC 233.66; Abundance of grassland species: plot type 262 263 only model AIC 325.53, vegetation only model AIC 385.17).

#### 264 **Discussion**

265 The efforts to restore ski-pistes have changed considerably since the demands for sustainable 266 erosion control arose in the 1970s. Restoration technology has made considerable progress in recent 267 years, and specific revegetation measures are available that make use of local seeds and plants that 268 are adapted to and suited for any elevation. In the long-term, in fact, sufficient protection against 269 erosion can only be guaranteed if stable, enduring and ecologically adapted sub-alpine and alpine 270 plant species become established (Krautzer et al. 2013, Klug et al. 2013, Rixen 2013). 271 Nevertheless, several thousand kilometers of ski-pistes still require restoration in the European 272 Alps. Above the tree line in particular, vegetation cover on the ski-pistes remains extremely low for 273 long periods after restoration (at least 10-12 years), despite the use of modern techniques such as 274 hydro-seeding (Barni et al. 2007). Worse still, the vegetation cover on high altitude machine-graded 275 pistes may deteriorate over time, illustrating that natural recovery may not occur in these managed alpine habitats (Roux-Fouillet et al. 2011). Only at elevations of several hundred meters below the 276 tree line does re-establishment of vegetation occur rapidly and reliably (Rixen 2013). 277

278 Despite the amount of research conducted, very little is known about the effect of ski-piste 279 restoration on animal communities. To our knowledge, no study on the effect of restoration on bird 280 communities has been published so far. In this paper, we therefore tested for the first time the 281 hypothesis that revegetation of ski-pistes of open habitat zones goes hand-in-hand with bird 282 community recovery. In terms of habitat structure, restored ski-pistes were in fact not significantly 283 different from natural grassland, thus suggesting that a successful restoration level was achieved. 284 Previous studies carried out on non-restored ski-pistes in open habitat areas have shown that plots 285 located in natural grasslands supported the greatest bird species richness and diversity and the 286 greatest grassland species density, whereas those in ski-pistes had the lowest values; moreover, 287 plots located beside ski-pistes did not support smaller numbers of bird species and diversity than 288 plots in natural areas, but they supported a significantly lower bird density (Rolando et al. 2007). 289 There was no difference in the overall bird community between restored ski-pistes and natural 290 grasslands, but there was a significant difference in grassland specialist species, suggesting that 291 habitat quality for this group in particular is affected by ski-piste type. More broadly, these results 292 show that the guild approach can reveal patterns not evident when considering the community as a 293 whole (Bishop and Mayers 2005, Caprio et al. 2008).

294 The present results suggest that restoration of ski-pistes may partially promote the recovery of local 295 bird communities. Species richness and abundance of birds were in fact significantly higher on 296 restored than on non-restored ski-pistes, independently of the species considered and the analyses 297 carried out. Nevertheless, bird community parameters (especially those of grassland species) of restored ski-pistes were still lower than those of natural grassland, despite the fact that the presence 298 299 of shrubs (i.e. rhododendrons) in grasslands tended to lower bird diversity. This suggests therefore 300 that an apparently successful restoration of ski-pistes may not be enough to promote a *complete* recovery of bird communities. These results are likely driven by the vegetation of the restored ski-301 302 pistes. Several studies have demonstrated that grass cover of ski-pistes is a major determinant of

303 local animal diversity (Caprio et al. 2011, Negro et al. 2010). However, equal grass cover of 304 restored ski-pistes and natural grassland does not necessarily prove they are ecologically equivalent, 305 because differences may still be great and significant in terms of density of grass species, which 306 remains lower on restored ski-pistes, or in terms of occurrence of alien plant species, which is 307 higher on ski-pistes, especially when hydroseeded (Barni et al. 2007). This means that, even though 308 grass cover is high, the vegetation of restored ski-pistes remains different from that of adjacent 309 pastures and, therefore, poorly attractive to local birds. Previous studies have shown that responses 310 of ground-dwelling arthropods to ski-piste restoration (as a consequence of hydroseeding with commercial mixtures) were contrasting. Restored ski-pistes were colonized by grasshoppers, which 311 312 were more abundant on ski-pistes than on the adjacent grassland plots, but ski-pistes and adjacent 313 grassland plots were used equally by ground beetles, and ski-pistes were avoided by spiders (Negro 314 et al. 2013). Birds feeding on epigeic invertebrates might be influenced by these changes (e.g. 315 alpine choughs were seen feeding on grasshoppers in ski-restored ski-pistes), but present results 316 suggest that overall attractiveness of restored ski-pistes was lower than that of natural grassland. 317 This study indicates therefore that restoration of ski-pistes of open habitat areas may promote the 318 complete recovery of local bird communities only if an integral recolonisation of the original 319 vegetal communities (which is essential to host invertebrates) is achieved. Otherwise, the recovery 320 will be significant (e.g. higher values of bird species richness and abundance than non-restored ski-321 pistes) but nevertheless, partial (e.g. lower values of species richness and abundance than natural 322 grassland). Considering that thousands of kilometers of ski-pistes have been already constructed in 323 the Alps, and that climate change will probably increase the potential conflict between skiing and 324 high-elevation bird species, the best conservation choice will be that of abstaining from, or at least 325 deferring, the construction of new ski-pistes. If construction of new ski-pistes is unavoidable, it is 326 vitally important that restoration measures follow restoration guidelines that represent today's state-327 of-the-art (Rixen 2013) and that original grasslands which are compatible with skiing activities are 328 preserved.

329 We wish to stress that successful restoration of ski-pistes will not solve eventual problems 330 connected with snow cover management. Snow cover of ski-pistes is very different from that of natural grassland because of the use of artificial snow produced by snow-making facilities and/or 331 332 the snow compression caused by skiers and heavy machinery. In both cases, the main effect is that 333 of postponing the time of melt-out (Rixen 2013). This causes a delay in vegetative growth and 334 flowering, which has been demonstrated to affect alpine butterfly communities (Rolando et al. 335 2012). Hence, it cannot be excluded that, all other things being equal, this phenological delay may 336 also affect bird communities, irrespective of the restoration status of the ski-pistes. Even naturefriendly management does not necessarily guarantee animal conservation. In ski-pistes of an alpine 337 338 open habitat zone whose vegetation cover never experienced any disturbance, a noticeable decline 339 in the abundance of most epigeic beetle species in patches with artificially increased accumulation 340 of snow was found (Kašák et al. 2013).

341 Much published research (as here) is based on models that take into account habitat and vegetation 342 cover (Caprio et al. 2001, Chamberlain et al. 2013). This kind of approach is adequate in depicting 343 and identifying major responses and processes, but much effort should also be made in order to 344 better understand underlying mechanisms, including fine-scale studies of the relationship between 345 birds, vegetation, snow cover and invertebrate availability. This in-depth analysis is needed to drive 346 management interventions to improve habitat conditions in alpine areas which are also already 347 threatened by climate change (Chamberlain et al. 2013). This suggests that, in addition to research 348 on the effects of ski-restoration, more studies on the effect of winter snow on birds and invertebrate communities of ski-pistes are desirable. For example, species such as Alpine Chough, Red-billed 349 350 Chough and Snowfinch are dependent on invertebrates during the spring and summer, whose 351 availability is likely to be affected by vegetation structure and snow cover. The effect of snow melt (including artificial snow) on plant and invertebrate phenology, both on and off pistes, and 352

353 consequently feeding ecology of high altitude grassland birds, should be a priority research topic in354 this field.

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### 360 **References**

- 361 Amacher-Hoppler, A. & Schoch, R. 2008. Remontées Mécaniques Suisses: Faits et Chiffres.
- 362 *Remontées mécaniques* Suisse, Berne.
- 363 Barni, E., Freppaz, M. & Siniscalco, C. 2007. Interactions between Vegetation, Roots, and Soil
- 364 Stability in Restored High-altitude Ski Runs in the Alps. Arct., Antarc., Alp. Res 39: 25–33.
- 365 Bayfield, N.G., 1996. Long-Term Changes in Colonization of Bulldozed Ski Pistes at Cairn Gorm,
- 366 Scotland. J. Appl. Ecol. 33: 1359–1365. doi: 10.2307/2404776
- 367 Bicknell, S. & Mcmanus, P. 2006. The Canary in the Coalmine: Australian Ski Resorts and their
- 368 Response to Climate Change. Geographical Research 44: 386–400. doi: 10.1111/j.1745-
- 369 5871.2006.00409.x
- **Bishop, J.A., Mayers, W.L.** 2005. Associations between avian functional guild response and
- regional landscape properties for conservation planning. *Ecol. Indic.* **5:** 33–48.
- doi:10.1016/j.ecolind.2004.10.001
- **Caprio, E., Ellena, I., Rolando, A.** 2008. Assessing habitat/landscape predictors of bird diversity
- in managed deciduous forests: a seasonal and guild-based approach. *Biodivers. Conserv.* 18: 1287–

375 1303. doi: 10.1007/s10531-008-9478-1

- 376 Caprio, E., Chamberlain, D.E., Isaia, M. & Rolando, A. 2011. Landscape changes caused by
- 377 high altitude ski-pistes affect bird species richness and distribution in the Alps. *Biol. Conserv.* 144:
- 378 2958–2967. doi: 10.1016/j.biocon.2011.08.021

- 379 Cernusca, A., Angerer, H., Newesely, C. & Tappeiner, U. 1990. Auswirkungen von Kunstschnee
- Eine Kausalanalyse der Belastungsfaktoren. Verhandlungen der Gesellschaft für Ökologie
  19:746–757.
- 382 Chamberlain, D.E., Negro, M., Caprio, E., Rolando, A. 2013. Assessing the sensitivity of alpine
- birds to potential future changes in habitat and climate to inform management strategies. *Biol.*
- 384 *Conserv.* **167:**127–135. doi: 10.1016/j.biocon.2013.07.036
- 385

386 Delarze R, Gonseth Y, and Galland P.1998. Guide des milieux naturels de Suisse: écologie-

- 387 *menaces-espèces caractéristiques*. Lausanne, Switzerland: Delachaux et Niestle.
- Elsasser, H. & Messerli, P. 2001. The Vulnerability of the Snow Industry in the Swiss Alps. *Mt. Res. Dev.* 21:335–339.
- 390 Fukushima, T., Kureha, M., Ozaki, N., et al. 2002. Influences of air temperature change on
- leisure industries case study on ski activities –. *Mitigation Adapt. Strateg. Glob. Chang.* 7:173–
- 392 189. doi: 10.1023/A:1022803405470
- 393 Gaunch, H.G. Jr 1984. *Multivariate Analysis in Community Ecology*. Cambridge University Press,
  394 Cambridge, UK.
- Hadley, G.L. & Wilson, K.R. 2004. Patterns of Small Mammal Density and Survival Following
  Ski-Run Development. J. Mammal. 85:97–104.
- 397 Isselin-Nondedeu, F., & Bédécarrats, A. 2007. Influence of alpine plants growing on steep slopes
- 398 on sediment trapping and transport by runoff. *CATENA* **71**:330–339. doi:
- 399 10.1016/j.catena.2007.02.001
- 400 Kašák, J., Mazalová, M., Šipoš, J. & Kuras, T. 2013. The effect of alpine ski-slopes on epigeic
- 401 beetles: does even a nature-friendly management make a change? J. Insect. Conserv. 17:975–988.
- 402 doi: 10.1007/s10841-013-9579-3

- Keßler, T., Cierjacks, A., Ernst, R. & Dziock, F. 2011. Direct and indirect effects of ski run
  management on alpine Orthoptera. *Biodivers. Conserv.* 21:281–296. doi: 10.1007/s10531-0110184-z
- 406 Klug, B., Markart, G., Meier. J., Krautzer, B. & Kohl, B. 2013. Ski run re-vegetation: a never-
- 407 ending story of trial and error? In: Rixen C, Rolando A (eds) *The Impacts of Skiing and Related*
- 408 Winter Recreational Activities on Mountain Environments. Bentham Ebooks

- 410 Koenig, U. & Abegg, B. 1997. Impacts of Climate Change on Winter Tourism in the Swiss Alps. J.
- 411 Sustainable Tour. 5:46–58. doi: 10.1080/09669589708667275
- 412 Körner, C. 2003. Alpine plant life. Springer, Heidelberg
- 413 Krautzer, B., Graiss W. & Klug, B., 2013. Ecological restoration of ski runs. In: Rixen C,
- 414 Rolando A (eds) The impacts of skiing and related winter recreational activities on mountain
- 415 *environments*. Bentham Ebooks.
- 416
- 417 Laiolo, P. & Rolando, A. 2005. Forest bird diversity and ski-runs: a case of negative edge effect.
- 418 Anim. Conserv. 8: 9–16. doi: 10.1017/S1367943004001611
- 419 Mackenzie, D. 1989. Alpine countries seek controls on skiers, builders and roads. New Scientist
- 420 Publ Expediting Inc 200 Meacham Ave, Elmont, NY 11003
- 421 Mosimann, T. 1985. Geo-ecological impacts of ski piste construction in the Swiss Alps. Appl.
- 422 Geogr. 5: 29–37. doi: 10.1016/0143-6228(85)90004-9
- 423 Negro, M., Isaia, M., Palestrini, C., et al. 2010. The impact of high-altitude ski pistes on ground-
- dwelling arthropods in the Alps. *Biodivers. Conserv.* 19: 1853–1870. doi: 10.1007/s10531-010-
- 425 9808-y

- 426 Negro, M., Isaia, M., Palestrini, C. & Rolando, A. 2009 The impact of forest ski-pistes on
- 427 diversity of ground-dwelling arthropods and small mammals in the Alps. *Biodivers. Conserv.* 18:
- 428 2799–2821. doi: 10.1007/s10531-009-9608-4
- 429 Negro, M., Novara, C., Bertolino, S. & Rolando, A. 2012. Ski-pistes are ecological barriers to
- 430 forest small mammals. *Eur. J. Wildl. Res.* **59:** 57–67. doi: 10.1007/s10344-012-0647-x
- 431 Negro, M., Rolando, A., Barni, E., et al. 2013. Differential responses of ground dwelling
- 432 arthropods to ski-piste restoration by hydroseeding. *Biodivers. Conserv.* 22: 2607–2634. doi:
- 433 10.1007/s10531-013-0544-y
- 434 Patthey, P., Wirthner, S., Signorell, N. & Arlettaz, R. 2008. Impact of outdoor winter sports on
- the abundance of a key indicator species of alpine ecosystems. J. Appl. Ecol. 45: 1704–1711. doi:
- 436 10.1111/j.1365-2664.2008.01547.x
- 437 Pechlaner, H. & Tschurtschenthaler, P. 2003. Tourism policy, tourism organisations and change
  438 management in Alpine regions and destinations: a European perspective. *Curr. Issues Tour.* 6: 508–
  439 539. doi: 10.1080/13683500308667967
- 440 R Core Team 2014. R: A language and environment for statistical computing. R Foundation
- 441 for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/
- 442

443 Rixen, C., Haeberli, W. & Stoeckli, V. 2004. Ground Temperatures under Ski Pistes with

- 444 Artificial and Natural Snow. Arct., Antarc., Alp. Res 36: 419–427.
- 445 Rixen, C. 2013. Skiing and vegetation In: Rixen, C., Rolando, A. (eds) The Impacts of Skiing and
- 446 Related Winter Recreational Activities on Mountain Environments. Bentham Ebooks
- 447

- Rolando, A., Caprio, E., Rinaldi, E. & Ellena, I. 2007. The impact of high-altitude ski-runs on
  alpine grassland bird communities. *J. Appl. Ecol.* 44: 210–219. doi: 10.1111/j.13652664.2006.01253.x
- 451 Rolando, A., Negro, M., D'Entrèves, P.P., et al. 2013. The effect of forest ski-pistes on butterfly

452 assemblages in the Alps. Insect Conserv. Divers. 6: 212–222. doi: 10.1111/j.1752-

453 4598.2012.00204.x

454 Roux-Fouillet, P., Wipf, S., Rixen, C. 2011. Long-term impacts of ski piste management on alpine

455 vegetation and soils. J. Appl. Ecol. 48: 906–915. doi: 10.1111/j.1365-2664.2011.01964.x

- 456 Sanecki, G.M., Cowling, A., Green, K., et al. 2006. Winter distribution of small mammals in
- 457 relation to snow cover in the subalpine zone, Australia. J. Zool. (London) 269: 99–110. doi:

458 10.1111/j.1469-7998.2006.00074.x

459 Sato, C.F., Wood, J.T. & Lindenmayer, D.B. 2013. The Effects of Winter Recreation on Alpine

460 and Subalpine Fauna: A Systematic Review and Meta-Analysis. PLoS ONE 8:e64282. doi:

- 461 10.1371/journal.pone.0064282
- Sato, C.F., Wood, J.T., Schroder, M., et al. 2014a. An experiment to test key hypotheses of the
  drivers of reptile distribution in subalpine ski resorts. *J. Appl. Ecol.* 51: 13–22. doi: 10.1111/13652664.12168
- 465 Sato, C.F., Wood, J.T., Schroder, M., et al. 2014b. Designing for conservation outcomes: the
- value of remnant habitat for reptiles on ski runs in subalpine landscapes. *Landscape Ecol.* 29:
- 467 1225–1236. doi: 10.1007/s10980-014-0058-3
- Scott, D., Dawson, J. & Jones, B. 2007. Climate change vulnerability of the US Northeast winter
  recreation- tourism sector. *Mitig. Adapt. Strateg. Glob. Change.* 13: 577–596. doi: 10.1007/s11027-
- 470 007-9136-z

- 471 Simons, P. 1988. Après ski le déluge. *New scientist* 117:49–52.
- 472 Titus, J.H. & Tsuyuzaki, S. 1999. Ski Slope Vegetation of Mount Hood, Oregon, U.S.A. Arct.,
- 473 Antarc., Alp. Res 31: 283–292. doi: 10.2307/1552259
- 474 Urbanska, K.M. & Fattorini, M. 2000. Seed Rain in High-Altitude Restoration Plots in
- 475 Switzerland. *Restor. Ecol.* **8:** 74–79. doi: 10.1046/j.1526-100x.2000.80010.x
- 476 Verner, J. 1984. The guild concept applied to management of bird populations. *Env. Manag.* 8: 1–
- 477 13. doi: 10.1007/BF01867868
- 478 Wipf, S., Rixen, C., Fischer, M., et al. 2005. Effects of ski piste preparation on alpine vegetation.
- 479 J. Appl. Ecol. 42: 306–316. doi: 10.1111/j.1365-2664.2005.01011.x
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496 Appendix I. List of the bird species recorded in the 49 plots. Frequency of occurrence is the number

497 of plots in which a certain species was observed/ the total number of plots per each plot type.

498 Values in brackets indicate the total number of individuals recorded. Guild classification was

- 499 according to Laiolo et al. 2004 (GE: grassland and ecotone species; SW: shrub and woodland
- 500 species)

Common name	Scientific name	Natural grassland	Non-restored ski- pistes	Restored ski- pistes	Guild
Common quail	Coturnix coturnix	6.12 (3)	0.00 (0)	0.00 (0)	GE
Cuckoo	Cuculus canorus	2.04 (1)	0.00 (0)	0.00 (0)	GE
Great spotted woodpecker	Dendrocopos major	2.04 (1)	0.00 (0)	0.00 (0)	SW
Red-backed Shrike	Lanius collurio	12.24 (6)	4.08 (2)	0.00 (0)	GE
Black Grouse	Tetrao tetrix	4.08 (2)	0.00 (0)	2.04 (1)	GE
Alpine chough	Pyrrhocorax graculus	0.00 (0)	0.00 (0)	51.02 (25)	GE
Jay	Garrulus glandarius	6.12 (3)	0.00 (0)	0.00 (0)	SW
Coal Tit	Periparus ater	4.08 (2)	0.00 (0)	2.04 (1)	SW
Skylark	Alauda arvensis	10.20 (15)	0.00 (0)	4.08 (6)	GE
Garden Warbler	Sylvia borin	14.29 (7)	0.00 (0)	0.00 (0)	SW
Lesser Whitethroat	Sylvia corruca	36.73 (18)	6.12 (3)	10.20 (5)	SW
Ring ouzel	Turdus torquatus	18.37 (9)	0.00 (0)	2.04 (1)	GE
Blackbird	Turdus merula	2.04 (1)	0.00 (0)	0.00 (0)	SW
Fieldfare	Turdus pilaris	2.04 (1)	0.00 (0)	0.00 (0)	GE
Mistle trush	Turdus viscivorus	2.04 (1)	0.00 (0)	2.04 (1)	GE
Black Redstart	Phoenicurus ochruros	36.73 (18)	24.49 (12)	53.06 (26)	GE
Winchat	Saxicola rubetra	65.31 (32)	57.14 (28)	24.49 (12)	GE
Rock-Thrush	Monticola saxatilis	20.41 (10)	0.00 (0)	6.12 (3)	GE
Wheatear	Oenanthe oenanthe	20.41 (10)	14.29 (7)	12.24 (6)	GE
Alpine accentor	Prunella collaris	4.08 (2)	0.00 (0)	12.24 (6)	GE
Dunnock	Prunella modularis	26.53 (13)	0.00 (0)	8.16 (4)	GE

White Wagtail	Motacilla alba	8.16 (4)	6.12 (3)	6.12 (3)	GE
Tree pipit	Anthus trivialis	44.90 (22)	6.12 (3)	24.49 (12)	GE
Water pipit	Anthus spinoletta	59.18 (29)	36.73 (18)	30.61 (15)	GE
Snowfinch	Montifringilla nivalis	14.29 (7)	0.00 (0)	0.00 (0)	GE
Chaffinch	Fringilla coelebs	20.41 (10)	8.16 (4)	0.00 (0)	SW
Bullfinch	Pyrrhula pyrrhula	4.08 (2)	0.00 (0)	4.08 (2)	SW
Linnet	Linaria cannabina	83.67 (41)	8.16 (4)	20.41 (10)	GE
Goldfinch	Carduelis carduelis	0.00 (0)	2.04 (1)	0.00 (0)	GE
Yellowhammer	Emberiza citrinella	18.37 (9)	2.04 (1)	14.29 (7)	GE
Rock bunting	Emberiza cia	4.08 (2)	0.00 (0)	0.00 (0)	GE
Ortolan bunting	Emberiza hortulana	2.04 (1)	0.00 (0)	0.00 (0)	GE

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**Table 1.** Mean  $\pm$  SD habitat cover and structure variables, bird species richness and abundance of 518 individuals in natural grasslands, non-restored and restored ski-pistes. Inter-plot differences were

tested with a one-way ANOVA. LSD post-hoc tests were used for pairwise comparisons of means.

520 \*P < 0.05; \*\*P < 0.01; \*\*\*P < 0.001; NS Not Significant.

	(1) Natural Grassland	(2) Non-restored ski-pistes	(3) Restored ski- pistes	Interplot differences	Significant pairwise comparison at $P < 0.05$
Habitat					
Grass cover (%)	$71.39\pm20.17$	$22.21\pm25.54$	$65.71\pm24.30$	F <sub>2,46</sub> = 22.49 ***	(1) vs (2) (2) vs (3)
Soil rubble cover (%)	$1.67\pm7.071$	$39.85\pm38.39$	$2.32\pm4.21$	F <sub>2,46</sub> = 14.88 ***	(1) vs (2) (2) vs (3)
Stone-rock cover (%)	$17.92 \pm 15.22$	$26.47\pm34.99$	$26.96\pm23.21$	F <sub>2,46</sub> = 0.66 NS	
Shannon habitat	$0.59\pm0.21$	$0.53\pm0.36$	$0.57\pm0.27$	$F_{2,46} = 0.87 \text{ NS}$	
Mean vertical structure	$17.92\pm14.88$	$3.94\pm3.41$	$15.04\pm10.02$	$F_{2,46} = 8.15 ***$	(1) vs (2) (2) vs (3)
CV vertical structure	$1.06\pm0.35$	$1.44\pm0.90$	$1.09\pm0.32$	$F_{2,46} = 2.074 \text{ NS}$	(_) ** (*)
Overall community					
Species richness	$6.28\pm3.16$	$2.65 \pm 1.87$	$4.71\pm2.97$	F <sub>2,46</sub> = 7.81 ***	(1) vs (2) (2) vs (3)
Abundance of individuals	$16.11 \pm 8.81$	$5.18\pm3.83$	$10.57\pm9.25$	F <sub>2,46</sub> = 9.02 ***	(1) vs (2) (1) vs (3)
Grassland guild					
Species richness	5.72 ± 2.89	$2.59 \pm 1.70$	4.43 ± 2.79	F <sub>2,46</sub> = 8.41 ***	(1) vs (2) (1) vs (3) (2) vs (3)
Abundance of individuals	$14.94\pm8.43$	$4.94\pm3.27$	$10.21\pm9.17$	F <sub>2,46</sub> = 6.87 ***	(1) vs (2) (1) vs (3) (2) vs (3)
individuals				6.87 ***	(1) vs (3) (2) vs (3)

**Table 2.** GLM of bird species richness and abundance of individuals of the overall community, and530of species richness and abundance of individuals of grassland species in relation to non-restored ski-531pistes, restored ski-pistes and natural grasslands (reference level), habitat parameters and altitude.532\*P < 0.05; \*\*P < 0.01; \*\*\*P < 0.001; NS Not Significant.

Overall Community			
Species richness			
		Std.	
	Estimate	Error	Р
Intercept	1.488	0.189	***
Non-restored ski-piste	-0.903	0.178	***
Restored ski-piste	-0.333	0.157	*
Shannon index of vegetation			
cover	0.673	0.258	**
Shrubs cover	0.21	0.096	*
Abundance of individuals			
		Std.	
	Estimate	Error	Р
Intercept	2.3009	0.2584	***
Non-restored ski-piste	-1.1874	0.2517	***
Restored ski-piste	-0.4754	0.2095	*
Shannon index of vegetation			
cover	0.8965	0.3542	*
Shrubs cover	-0.278	0.1237	*

Grassland species guild			
Species Richness			
		Std.	
	Estimate	Error	Р
Intercept	-0.316	0.743	0.67
Non-restored ski run	-0.828	0.180	***
Restored ski run	-0.301	0.164	*
Shannon index of vegetation			
	0 655	0 205	*
cover	0.033	0.293	
Altitude	0.001	0.000	*
Shrubs cover	-0.225	0.088	*
Abundance of individuals			
		Std.	
	Estimate	Error	Р
Intercept	0.703	0.461	0.12
Non-restored ski run	-1.138	0.126	***
Restored ski run	-0.400	0.105	***
Altitude	0.001	0.000	***
Shrubs cover	-0.229	0.050	***

Fig. 1. Biplot of a principal component analysis (PC1 vs. PC2) where both environmental 536 537 descriptors and survey plots are plotted together. As a matter of clarity, to avoid plotting too many confounding points (i.e. 49 survey plots plus seven descriptors), the distribution of survey plots for 538 539 each plot type is synthetically represented by centroids (i.e. the weighted mean of survey plots). 540 Soil, percentage of soil-rubble cover; Rock, percentage of stone-rock cover; Shrub, percentage of 541 shrub cover; Grass, percentage of grass cover; H'hab, Shannon diversity of the habitat; CV Height, 542 heterogeneity of the vertical component; Height, mean height of the vertical component. Dots 543 indicate environmental descriptors (habitat structure variables), squares indicate centroids of survey 544 plots.

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548 Fig. 2. Average value of species richness of grassland species per point count in natural grasslands,

549 non-restored ski-pistes and restored ski-pistes. Bars are standard errors.





Fig. 3. Average value of number of individuals of grassland species per point count in naturalgrasslands, non-restored ski-pistes and restored ski-pistes. Bars are standard errors.

